A Division of
Massachusetts
Institute
of Technology

The Charles Stark Draper Laboratory

68 Albany Street, Cambridge, Massachusetts 02139 Telephone (617) 864-6900

LUMINARY MEMO # 239

TO: Distribution
FROM: D. Eyles
DATE: February 22, 1972
SUBJECT: EMPs to display H and $\dot{H}$ on the DSKY.

EMP 107 designates an erasable memory program to display landing radar altitude and altitude-rate on the DSKY in the event that the tape meters are broken. It all started when the glass broke on Apollo 15. There are two uses for this data: (1) to update the AGS, and (2) to compare to the PGNCS calculated values, especially during P66.

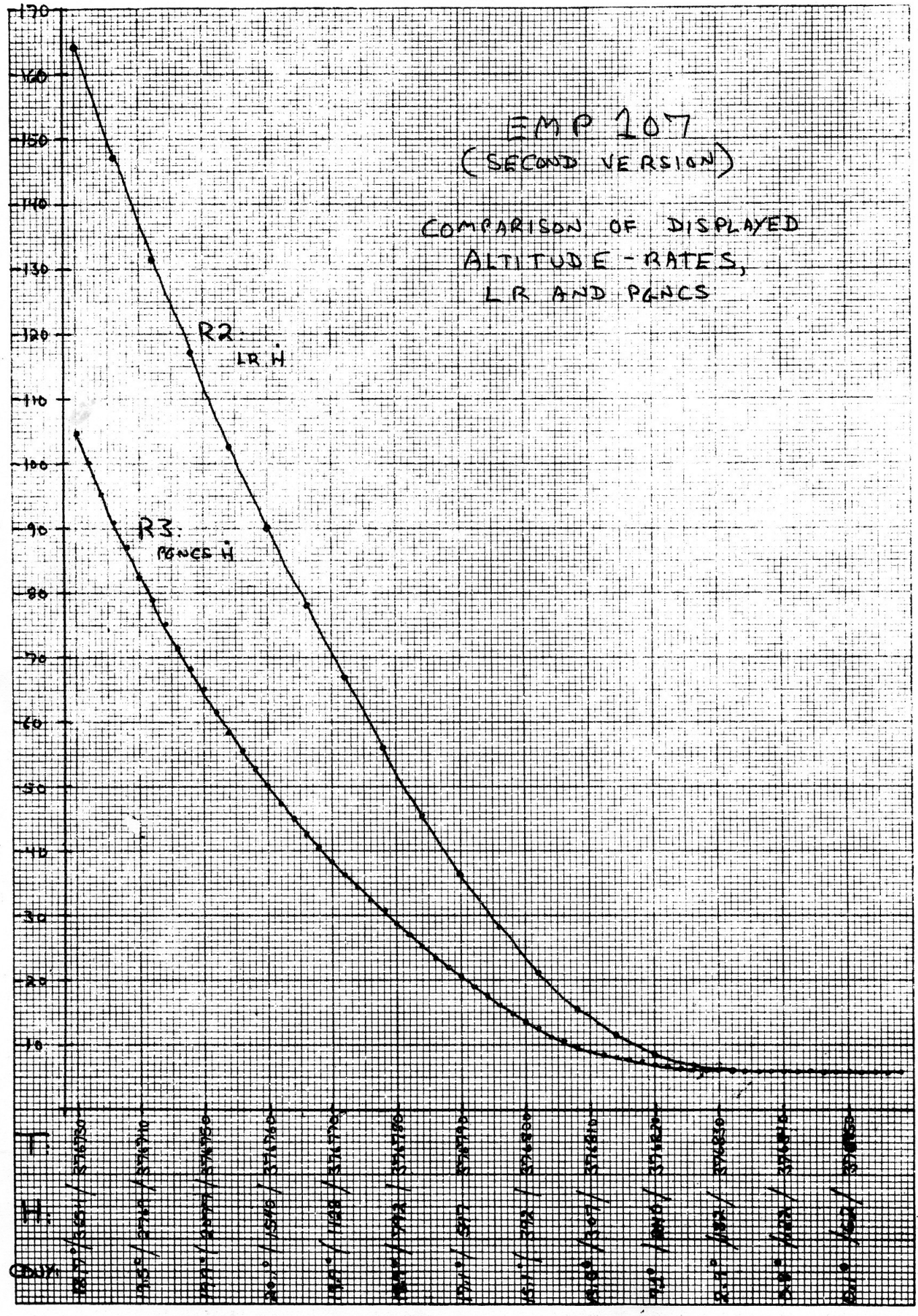
Two different erasable programs have been concocted and tested for this purpose. They have in common that they are executed between the end of Servicer and the landing guidance, and are initiated by loading the starting address of the erasable program into the upper order half of AVGEXIT, after ignition, when AVGEXIT is loaded with the double-precision address of LUNLAND. (Thus when the DXCH Z at the end of Servicer transfers control to the erasable program, EBANK is set to 7.). They both use noun 99 for display.

They differ in philosophy. The first presented here assumes that the PGNCS state vectors are valid. The second assumes only that the program sequencing is healthy. The second is preferable, and it is the second version which is documented as EMP 107.

The first of the two versions extracts "raw" radar data in just the same way the radar update routine extracts ΔH and $\Delta \dot{H}$ for use in updating the position and velocity vectors. For H, this consists of multiplying the scalar radar reading HMEAS, by the projection of the range beam vector on the unit position vector. For $\dot{H}$, the process is somewhat more complicated because the direction of the radar x-beam and the sensed velocity alone do not provide enough information to separate the velocity due to altitude-rate from that due to horizontal motion across the surface. This requires use of the PGNCS velocity vector. (Note that the three beam velocities would allow this separation to be made, but this would require a more complex erasable program than there is room for.) The unit position vector is also used in the $\dot{H}$ extraction. Implicit in this discussion is that the vehicle attitude, described by the XNBPIP vector, is also required for both extractions. Thus, in this version of the EMP, a working IMU and valid PGNCS state vectors are assumed -- in calculating values for comparison to PGNCS values. There would seem to be an inconsistency there. On the other hand, the H and $\dot{H}$ displayed, in R1 and R2 of N99 respectively, are true altitude and altitude-rate, independent of the LM's horizontal velocity and attitude. This version is attached as Appendix A.

The second version of EMP 107 takes a different approach. To begin with, it recognizes another contradiction: if the tape meters are broken and the DSKY is displaying radar data, no direct, simultaneous comparison of PGNCS and radar data is possible. Consequently, PGNCS altitude-rate is rescaled and displayed in R3 of N99, to the nearest tenth of a foot per second. (The same thing cannot be done in the earlier version without using an additional block of erasable memory.) However, the main difference between the two versions is that the second displays exactly the values that would be seen on the meters if they were working. HMEAS and

VMEAS (for the x-beam only) are simply scaled and displayed, in R1 and R2 of N99 respectively. Thus the PGNCS state vectors need not be valid and the IMU need not even be working. Only the radar read routine (and Servicer which calls it) need to be functioning. The disadvantage is that the displayed values are not true altitude and altitude-rate. R1 is a slant range. R2 is a velocity which contains a contribution due to horizontal motion. Indeed this velocity overflows the display scaling, and is set to zero, until (roughly) the re-acquisition of radar data after high-gate. And it does not represent true $\dot{H}$ until the vehicle's attitude is erect. A plot on the next page, taken from a simulation of a fully automatic landing, shows how the $\dot{H}$ displayed in R2 converges on the true (PGNCS) altitude-rate .


EMP 107
(SECOND VERSION)
COMPARISON OF DISPLAYED
ALTITUDE - RATES,
LR AND PGNCS
R2:
LR Ḣ
R3:
PGNCS Ḣ
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
T:
H:

Appendix A

Initiation:

After Ignition: V 21 N 1 E 1251 E 605 E

Display:

V 16 N 99 E (R1: H_{LR}; R2: H_{LR}; R3: garbage)

Validity:

R1 is valid when the ALT light is out. R2 is valid when the VEL light is out.

604	00000	reserves VAC4	
605	34746	CA	ZERO
606	54604	TS	VAC4USE
607	06060	TC	INTPRET
610	76634	RTB	VLOAD*
611	67501		POSINDEX
612	26003		HBEAMNB, 1
613	50305	VXM	DOT
614	02137		XNBPIP
615	03537		UNIT/R/
616	54205	DMP	SL
617	03655		HMEAS
620	20214		11D
621	77605	DMP	
622	26063		HSCAL
623	02172	STORE	WWPOS
624	77776	EXIT	
625	44744	CS	ONE
626	61462	AD	VSELECT
627	00006	EXTEND	
630	62425	BZMF	LUNLAND

631	06060	TC	INTPRET
632	54345	DLOAD	SL
633	03653		VMEAS
634	20215		12D
635	62605	DMP	PDVL*
636	26071		VXSCAL
637	26025		VXBEAMNB, 1
640	63305	VXM	PDVL
641	02137		XNBPIP
642	03527		V
643	52352	VSL2	VSU
644	03702		VSURFACE
645	44241	DOT	BDSU
646	53361	VXSC	VAD
647	00003		2
650	03527		V
651	54241	DOT	SL
652	03537		UNIT/R/
653	20211		8D
654	02174	STORE	WWVEL
655	77404	BOVB	EXIT
656	62425	CADR	LUNLAND
657	12425	TCF	LUNLAND

Appendix B

Initiation:

After Ignition: V 21 N 1 E 1251 E 661 E

Display:

V 16 N 99 E (R1: H_{LR}; R2: $\dot{H}_{LR}$; R3: $\dot{H}_{PGNCS}$)

Validity:

R3 is always valid. R2 is valid when the VEL light is out and R2 is non-zero. R1 is valid when the ALT light is out.

```
660   00000   reserves VAC5
661   34746   CA      ZERO
662   54660   TS      VAC5USE
663   31462   CA      VSELECT
664   67752   AD      OCT37776
665   54000   TS      A
666   00715   TC      715
667   06060   TC      INTPRET
670   41345   DLOAD   DMP
671   03653           VMEAS
672   26071           VXSCAL
673   77461   SL      EXIT
674   20223           18D
675   10121   CCS     OVFIND
676   00710   TC      710
677   00712   TC      712
700   00710   TC      710
701   00712   TC      712
702   32176   2DEC
703   12173    +.820209962
704
705           unused
706
707
```

```
710   54154   TS      MPAC
711   54155   TS      MPAC +1
712   06060   TC      INTPRET
713   02174   STORE   WWVEL
714   77776   EXIT
715   06060   TC      INTPRET
716   57545   DLOAD   DCOMP
717   03655           HMEAS
720   54205   DMP     SL
721   26063           HSCAL
722   20212           9D
723   16172   STODL   WWPOS
724   03474           HDOTDISP
725   42405   DMP     SL4
726   00703           702
727   02176   STORE   WWBIAS
730   77776   EXIT
731   34746   CA      ZERO
732   54121   TS      OVFIND
733   12425   TC      LUNLAND
```